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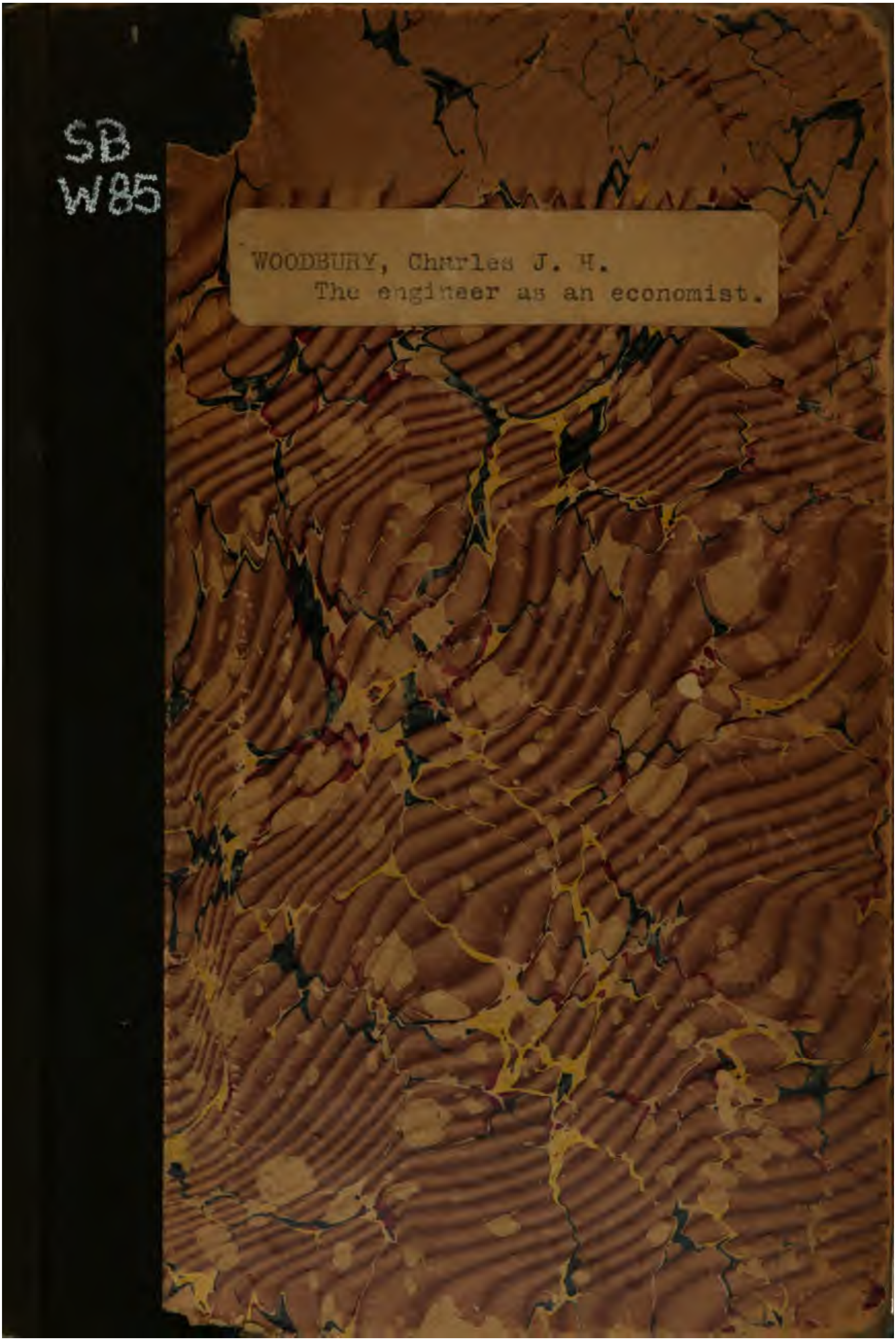

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The engineer as an economist.

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THE ENGINEER AS AN ECONOMIST

AN ADDRESS
GIVEN AT THE COMMENCEMENT EXERCISES
OF THE

THOMAS S. CLARKSON
MEMORIAL
SCHOOL OF TECHNOLOGY

JUNE 9, 1905

BY

C. J. H. WOODBURY, BOSTON, MASS.

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POTSDAM, N. Y.
1905

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THE THOMAS S. CLARKSON MEMORIAL SCHOOL
OF TECHNOLOGY, POTSDAM, N. Y.,
JUNE 9, 1905,

BY

C. J. H. WOODBURY, A.M.
BOSTON, MASS.

The personal reminiscences inspired by a commencement blend into those of historical retrospect, whose last chapter is of to-day, and whose relations to the proximate future rest upon the developments of past time.

Forty centuries look down upon each of us day by day as much as they did upon the legions of Napoleon at the battle of the Pyramids; and we in turn must depend upon the forty centuries for the heritage of enlightened civilization, which, in its ever-widening course from the Orient, along the northern littoral of the Mediterranean, swept over Europe, receiving year by year from nation after nation an enduring contributionship of whatsoever may serve as a beneficence to the greater number of mankind.

The endowments of life have been extended from the few to the many, to whom the luxuries of one generation have continued to become the proverbial necessities of the next, for generation after generation, until there is a demand for more in food, clothing, habitation and the ameliorations of existence beyond what is necessary to support life for the time being.

Famine and pestilence are now of barbarism, better nourishment has doubled the average span of life since the middle ages, and within the last century the senility of the seventh age of man has been postponed half a score of years.

This change for the better requires more than the dynamic force of the individual can produce, and this deficiency of initial might is supplied in civilized countries from the service of machinery, the segregation of skilled artisanship, and the utilization of products of lower civilizations where conditions of life are simpler, under the indulgences of more generous nature.

To supply these advantageous conditions in modes of life requires a concentration of the resources of the whole world, as well as application of the combined skill of enlightened mankind.

These blessings have been vouchsafed upon humanity as a result of the work of the engineer, whatever may have been the title now given to him who can build better than a layman.

From the Aryan migration, when the member of a moving colony who could bridge streams was the leader, and this term of the greatest bridge builder became fixed in language as a supreme title which Roman emperors took from their priesthood, and surviving that dynasty, Pontifex Maximus has since been conferred upon the head of the See at Rome.

In its secular phrase the title of engineer has been an honorable one, indicating an occupation in the forefront of civilization, ministering to the weal of humanity.

Like many towns in the old countries, the world's history is a succession of groups of events, each collection having a common purpose to build anew from old material. Each epoch in this development of material resources has been marked by some trend of improvement in thought and action which has been instrumental to the enlightenment of to-day.

It may be worth the while to cite several of the best known of these steps, which appear to have been especially contributory to the establishment of conditions requiring the work of the engineer in its application to the general welfare.

Beginning with the individual unit, Christianity, through its propaganda among the Roman trade unions, which were far more closely organized than their successors of to-day, inspired the lowly with the communistic heresy that every man had a soul, at a time when even the most advanced Greek philosophy limited immortality to the aristocracy; and by the inculcation of the Jewish Sabbath, it provided for work at higher efficiency during the six days.

These principles went further than the outward church, even as they have encompassed the whole world to-day, and were doubtless the cause of the remarkable revival throughout Roman polytheism in the year 200, when the various deities were relegated virtually to saintships, with an ethical head pre-eminent over all.

The next step was the downfall of the Roman empire, through the excessive taxation which was necessary to support that great centralization of power, at the time when its internal strength was impaired by slavery diffused throughout the empire to such an extent that every Roman was surrounded by those ready to become enemies the moment that opportunity afforded.

This slavery was not confined to unskilled labor and menial services, but reached to the highest classes of artisanship, and even the professions, particularly that of medicine.

But this downfall did not occur until the Romans had established a system of law which provided a defence for every individual in all his relations of person and property.

While it has been said that peace hath her victories no less than war, it is a fact that the records of wars are better known than the modest activities of peace. The invaders of Rome were too few to materially change the population, and gave the people that liberty which is merely the change of one despot for another. The Roman law survived conquests, and in every conquest the defeated party gains victories by imposing its customs upon the victors.

The magnitude of the great work of the Roman government in the establishment of its law and in its dissemination throughout Europe, where it remained after the fall of the empire, is marked by the fact that these laws were continued by the conquerors in the Latin language, and through this means the principles of the Romans were maintained throughout Europe, and became a heritage of civilization unto the present day.

The dark ages represented the time necessary to reorganize civilization from the degeneration of skilled labor, resulting from the economic fallacy of slavery, which was all the more pernicious on account of the high class of the bondsmen; and, while attention is often called to the fact that learning was almost entirely possessed by the clergy, yet it is often overlooked that the strength of the church was due to the fact that it was recruited by the principle of selection from fresh blood, and not continued by inheritance, and that it required generations of efforts of the monks to establish the character of honest manual labor.

The cultivation of land under serfdom was so inefficient that relatively large areas were required, and the population increased so rapidly in the absence of great wars, that it became so congested in Germany that every sixth year one man in six was selected by lot and expatriated, to "go to a place he wot not of."

Information of other countries, both as to product and demand, is not merely advantageous, but an essential preliminary to the exercise of that barter which constitutes foreign trade; and this knowledge was obtained by the Crusaders, who gained the education of travel, and their retreat brought into Europe oriental goods, tropical products and ideas of luxury.

The lessons were not always pleasant ones; one of the most notable being that of Montgolfier, the French knight, who was taken prisoner by the Saracens and sold into slavery to the Moors, who kept him at labor in their paper mills at Bagdad, where he toiled for many years; and on his return to his home in southern France he established paper making in Europe in mills which are still operated by his descendants, who gave to the world the pioneer aeronaut of that name.

The Saracens still held their dearly bought victories in remembrance, and were averse to the trespass of foreign caravans on their territories for trade with the Franks.

Then began the mania for exploration by the maritime nations, eager for trade with the Indies, and pushed by the crowded condition at home of those eager for conquest and colonization.

These developments were slow, but never retrogressive, and prepared the nations for continual advance, which called for new methods.

The services of the engineer were thus required for the output of industry to distant countries and the return of the luxuries of the fertile tropics, the maintenance of congested communities in health, and the better protection of the person by adequate clothing.

The prevailing direction of the work of the modern engineer has trended towards applications to the welfare of private individuals rather than to that of the government, especially in its military relations.

Life has been extended and health improved in the congestion of cities largely by the general installation of systems of water supply and sewerage; while, in the further concentration of employment, forced ventilation has rendered mines healthy and made the modern crowded office building a sanatorium, and in like manner added to the efficiency of the labors of the occupants.

Artificial refrigeration is a marked instance of the economy of engineering science applied to the general welfare, in its frugal checking of waste and its extension of the variety as well as improvement in food supplies.

An early indication of the segregation of industry into manufacturing appears to have been the separation of cloth making from the household to what eventually became a mill, where the production of this new industry made clothing more abundant because of its lesser cost, until there was a surplus.

Invention has followed invention until the contributionship of machinery has reduced the cost of the product.

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POTSDAM, N. Y.
1905

Solutions of constructive problems have revealed others, and within a few years the centre of engineering skill has shifted like a whirlwind to meet the new issues.

The wider insistence for the luxuries of civilization has made them a necessity, and these betterments must be supplied to a greater number; and in the same spirit there is a demand for a reduction of the time of labor; therefore, to meet these conditions costs of operation must be reduced, and the efficiency of productive methods increased.

The highest problem of the engineer has ceased to be how to do things, for that is well known, but it is how to do them cheaply; the problems are fundamentally those of economics.

When the application of steam to ocean transportation became possible it was at once demanded by the governments, in order to establish quicker means of communication with colonies, and also the use of the mails for the development of closer commercial relations, years before it was thought possible that steam navigation could be used exclusively for freights.

The side-wheel boats, with engines using steam at fifteen pounds pressure, required so much space for engine, boilers and fuel as to warrant the prophecy that a steamer could not cross the Atlantic, had it not been for the reinforcement of sails in these fully rigged steamships.

Once that ocean steam navigation was initiated, then came the economical applications of engineering for the reduction of expenses, and resulting in the wider use of steam vessels, and for longer voyages.

Remembering that every saving of weight and space devoted to machinery and coal gives a similar accommodation for cargo, the combined result of the substitution of propeller for side wheels, high-pressure steam, compound engines, the use of steel in place of iron, and redesigning of the lines taken from sailing vessels to those suited for iron steamships, the aggregate economies have reached to the enormous extent that the combustion of a ton of coal now transports across the Atlantic over fifty times as much cargo as fifty years ago; and the mercantile world is awaiting with interest the result of the renaissance of the original rotary engine in its modern application in the form of the steam turbine for the propulsion of vessels.

The highest type of engineering economies has not been applied to the ocean greyhounds, but in the less conspicuous freight steamers of moderate speed and large size, where the question of interest on the property in transit has been an element in the problem of speed; equating between the two in order to obtain minimum cost, less speed consumes a smaller amount of coal, greater speed secures a smaller interest charge on the trip. These economies have been developed until the aggregate result is expressed by the fact that there are many vessels in which the combustion of a pound of coal will propel a ton of cargo and its share of the vessel eleven and two-thirds miles.

In more commercial terms, freight has been transported across the Atlantic for 56 cents a ton; or to apply the change to the comparatively recent development of ore deposits at the Lake Superior region, the cost of transportation of ore through the lakes from Superior to Erie has diminished from $3 to 55 cents a ton.

These figures include terminal charges for loading and discharge, in which the engineer has applied his skill in the economic handling of material, particularly that which is in bulk. Ores, coal and grain are handled by methods adapted to each material; while the huge grain elevators, built with the wisdom of a modern Joseph, forfend cities and nations against famines which would otherwise threaten them.

These new conditions of water transportation have provided for increased tonnage, both as to single cargoes and the additional number of voyages by greater speed of transit; and this serves as an illustration of the results of engineering economies established through the concentration of units.

For the purposes of comparison, it was recently desired to obtain a photograph of a harbor in a large eastern seaport, to compare with an old ambrotype from the same point of view; and it was found that it was impossible to select a time when there was a number of boats in the field of the camera equal to those shown in the early picture; and examination of statistics revealed that, while the tonnage of the freights at this port had increased in quantity, the number of vessels had diminished.

Since the introduction of steam navigation the Lloyds and other marine underwriters have had in their service the ablest of steam engineers; but the great business of fire underwriting remained a clerical occupation, betting against the chance of fire, until less than a generation ago, when the profession of insurance engineering was established to apply scientific methods to the measure of existing hazards, and, beyond that, for the initiation of means for the diminution of the occurrence of fires, the reduction of loss by efficient apparatus, and the resistance to flames by suitable construction.

On the principle that it is cheaper to prevent a fire than to pay a loss, insurance companies all over the country place at the service of their clients engineers who will give professional services upon the construction of buildings, organization of fire-extinguishing equipment, installation of lighting apparatus, and even to details of lubrication and the operation of machinery.

Through corporate management in similar lines the English have developed, by their engineers, economies in the generation and utilization of steam for operation of mills, which accomplished results far superior to those in this country until within recent years, when the precedents did service to good designers who were also good copyists.

Boiler insurance companies in this country also furnish to their clients expert service in the design of steam plant for economy of fuel as well as security.

The engineering problem of to-day is a financial problem; it is not merely to build and to operate, for both are common knowledge in regard to almost every type of work, but it is how to build with lowest reasonable conditions of annual cost of the investment, and how to operate with lowest reasonable conditions of annual expenditure; and neither of these problems may require the fewest dollars, but perhaps demand amounts beyond the dreams of avarice.

Depreciation from wear and tear forces itself into engineering problems as surely as human mortality into actuarial work; and, beyond this, the iconoclasm of sudden impairment from subsequent invention in the unknown future threatens like a sword of Damocles.

As a simple instance of an engineering problem in economics, take that of the pipe from a large pump to deliver a certain number of gallons a day into a reservoir.

The cost of such pipes of several diameters laid in the trench may readily be estimated, and the annual charge of interest and depreciation ascertained, also the annual interest on the cost of excavating and filling the trench; these items would give the annual cost of installation of pipes of several diameters, which would be clearly the least with the smallest pipe.

The other element is that of the annual cost of pumping the water, which would be the greatest with the smallest pipe and the least with the pipe of the largest diameter, on account of the lesser friction with the larger pipes.

While this data might be equated and the minimum solved by the calculus, the average engineer is generally far enough from his school days to plot the two sets of data on cross-section paper, the one above the other, and quickly determine the result graphically from the curve with far more accuracy than that of the formula from which was computed the friction of the water forced through the pipe.

This pipe problem suggests another occurrence which is frequent in engineering work. The pipe may leak, but it may cost less to suffer the waste by leakage than to excavate and repair; there are many leaks which are lesser evils.

It is trite to mention that, in commercial affairs, successful results are dependent upon accurate forecasts of the future.

The one who correctly estimates whether present events will cause market prices to rise or fall is able to buy in the cheaper and sell in the dearer market.

But the responsibility of judging futurity is more exacting upon the engineer, for while the merchant may be able to close the transaction in case of error in judgment, and to protect himself by escaping with slight loss, instead of awaiting the finality of a larger one, the permanency of engineering work does not permit any escape from the ruthless logic of events, and work once begun must be carried to completion.

Some economies are those of the future and not of the present; as lumbering is now conducted under the supervision of the most efficient combination of technical skill and practical experience, and the woodmen who spare the smaller trees, looking ahead for the provision of another crop of the same species perhaps seventy years hence, instead of making a devastation and calling it industry, obtain less from the forest to-day, but more is expected as a permanent return on the capital.

The decadence of nations resulting from the denudation of forest districts presents some of the most deplorable instances in history, as is shown by the results in Palestine and in Spain. On the other hand, the great work of engineers in the development of fertility by irrigation and the arboreal growth which follows it in the western part of this country have warranted plans for the further extension of this work over the nine hundred thousand square miles of territory which are available for the purpose; and it may be expected throughout these enormous tracts that the words of the prophet will come to pass, in that "the desert shall rejoice and blossom as the rose."

On the northern shore of Massachusetts Bay the peninsula of Nahant juts out into the sea, forming by its natural contour one of the most picturesque points on the Atlantic coast. After the Puritans purchased this tract from the Indians for a jewsharp, two hundred and seventy-five years ago, it was subdivided among the settlers of the adjacent mainland, on the condition that each holder should fell all of the forest trees upon his allotment within six years, as a condition of acquiring title to his share; the purpose being to convert the peninsula into a large grazing tract, which could be easily defended against bears and wolves by a watch which was kept night and day on the isthmus. Following the removal of the trees, this land soon became sterile, and was used only for a few fishing huts until about seventy-five years ago, when a retired man in affluent circumstances purchased a large quantity, and accomplished the reclamation of this beautiful spot by planting trees.

The regularity of operation is an important element in the productive work of a machine whose economy may be reduced by intermittent operation; but, in any event, fixed charges of rent, interest, depreciation from subsequent invention, and even to a certain extent the impairment of time, are essential considerations.

For example, it is ordinarily cheaper to drive piles by machinery than by hand; and yet there are occasional instances where small amounts of work are to be done in places difficult of access, where it is necessary for the gang of men to work intermittently, either in moving the piles to their site or changing the position of machinery; and then, instead of waiting while the piles are driven by power, they may be employed in raising the hammer by the direct pull of a number of men, after the manner in which this work was done years ago.

A consideration of a steam engine plant solely on the basis of the cost of fuel would be short-sighted and extravagant, because those engines which are more economical in fuel are of a greater first cost, which will render the final results frequently excessive for irregular work.

In the case of a manufacturing establishment operated by water wheels, it frequently becomes necessary that provision be made for supplementary power, to be available during periods of drought; and it is a matter of simple estimate and computation to determine the class of steam power plant preferable for any conditions of affairs wherein the annual use of the engine may be an estimated factor, and the final results for a plant operating perhaps six weeks in the year may warrant only a cheaper type of steam engine and boiler, wasteful as to fuel, but economical as to its first cost and depreciation. On the other hand, if the steam from these boilers may be used advantageously for heating during a certain portion of the year, or for bleaching or dyeing continuously, this element of the problem may be modified; and if proposed extensions to the establishment in the near future will require a more extended use of this supplementary power, another element will be introduced into the problem which may warrant a more expensive plant, of the highest degree of steam economy.

In lubrication it frequently is advantageous to use greater quantities of oil for the reduction in the power cost. It required many years for the textile interests to learn that free lubrication of spindles was more economical than a limitation in the quantity of oil, which lubricated, but with greater friction; yet this may not be accepted as a truism, as it is modified by the cost of power, whether it be from steam and measured by shovelfuls of coal, or whether from an ample water power, where the cost is not increased by raising the gate.

A manufacturer of an article by a chemical process in general domestic use, which made a competitive product not protected by either patents or by the tariff, believing that it would be advantageous to introduce technical skill in the works, employed a professor of chemistry from a leading college, and was surprised that the professor did not give any attention to the main process, but began the most critical examination of the waste products, from which a number of substances of great value were obtained.

Railway transportation could not be established until the development of manufacturing stimulated the output of mines, and the necessity for their transportation and that of raw material and finished goods required cheaper means for moving these products in large quantities.

Steam transportation has not supplanted the need for horses, as was anticipated by the farmers who were impelled for that reason to make such attacks upon the surveying parties for the early English railways that pugilists were employed to pose as the head of the parties, and to strike from the shoulder when the protests became more than verbal.

Great as may be the amounts of material transported by railway, all of it, excepting that for export, is teamed at least twice, and much of it more than twice.

It appears as if the lessons of the Romans in highway building had been ignored in this country, and that the cost of tributary transportation by team was unnecessarily excessive; although the problem of minimum cost must be equated between the annual expense of a good highway and the amount of teaming which it bears.

For example, in lumbering it would not be warrantable to build any more of a highway than a cleared strip through the forest, where temporary snow roads may be made in winter.

The type of pioneer engineering to devise and build a railway has passed away, and its contributions of precedents in the construction of road bed and rolling stock have become formulated and organized, so that when a railway is to be built and put into operation every occurrence can be foreseen and due provision made.

For the maintenance and operation of the line there is constant need of the economies of engineering in the systematic methods of providing for every emergency tending to impair the continuity of service, in the application of every degree of labor and material; to avoid the wastes of duplication, when to provide temporarily and when to build permanently are problems of modern engineering.

The development continued until the speed of passenger traffic approached the safe limit of centrifugal force of chilled iron car wheels, and then the introduction of steel-tired car wheels enabled the further augmentation of speed.

The power of the railway influence was indicated a few years ago, when, like a Joshua, it changed the standards of time, and not only schedules of train service, but the goings out and comings in of the whole people conformed to the new conditions.

Moreover, be it remembered that this act, like others on the part of those made conservative by great responsibilities, provided for ameliorations in the infinite variety of affairs, from the uniformity of a day's labor in factories up to contracts of the greatest magnitude.

It is not possible to consider one great development without also meeting the tributaries which it has called into being; and the immense engineering operation of the railway system was undoubtedly the cause of the demand for watches, which must be produced at low cost; and the wonderful mechanical engineering work which manufactured the American automatic machine-made watch is one of the modern triumphs of engineering economies.

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To such an extent has this type of automatic machinery been developed that a factory devoted to the manufacture of cheap but quite regular watches produces four watches a day for each employee, including everybody engaged in the service of the establishment in any capacity whatever, even the teamsters and night watchmen; and the price at which some very cheap watches are sold indicates a still larger rate of production.

Vast as may be the output of watches, their use is largely confined to those within easy range of railroad transportation. It is the need for their use, and not their cost, that makes the demand for watches, for no one need be prevented by cost from owning a watch of some grade.

The cry of modern life, like that of the dying Queen Elizabeth, "Millions for a moment of time," has been fulfilled by the telegraph, sending its messages across continents and beneath seas to the uttermost parts of the earth; and by the telephone, which provides a path for the personal usage and its rebounding answer, which furnishes that conference needful for every commercial transaction. It bestows more than a saving in time; it makes a creation of results.

How much the potentiality of the individual is increased by these means is beyond the ken of those whom it serves; statistics cannot enumerate its economy, nor flight of fancy portray its results.

A few years ago enormous expenditures were required to double the wires and make corresponding alterations in the central station plant, to provide metallic circuits, to avoid disturbances to the electrical transmission of speech resulting from the effect of other electrical systems upon single lines with grounded returns.

At a later day even greater outlays have been devoted to the substitution of new types of switchboards, which save to the subscribers the few seconds necessary to turn the crank in calling the central office.

In the face of these lavish investments the economies of the engineer have materially diminished the cost of telephone service, as well as improved its quality.

The economic demand is for time, — the one thing which mankind cannot modify except by immediate transmission of current intelligence, quicker transportation in its reduction of otherwise available time, and artificial illumination in the utilization of unavailable time.

The more extensive introduction of illuminating gas has followed the result of economies by the united effort of engineers and chemists, primarily in the utilization of by-products, and later by fundamental economies in methods of gas generation.

Electrical illumination has been a new art wholly within the province of engineering, and, while its merits were fully appreciated from the first, yet the cost restrained its introduction from reaching a high percentage of development until the tributary expenses were reduced.

In prime movers it extended the development of engine and boiler economies, it has encouraged the return to first principles in the steam turbine, and through its patronage of the impulse water wheel has applied a new art to the utilization of the energy of cascades half a mile in height in the far west, which had hitherto descended unvexed to the lowlands, and has harnessed their power to useful work hundreds of miles distant.

An engineer is fundamentally a constructor and operator, while in an inventor the constructive sense is as apt to be as deficient as his proverbial lack of commercial ability. The invention of the Bessemer process of making steel was one of the most brilliant productions which ever adorned the results of an inventor; yet it required the work of many engineers to reduce its costs until it could be produced cheaper than wrought iron.

The changed conditions to which the rails of a certain railroad were subjected by the substitution of motors under each car, in place of one locomotive to a train, caused an alarmingly rapid wearing of rails, although of a type of steel which had been used satisfactorily for a long time; under the new conditions of attrition these rails in some places would last only six weeks, but on the advice of an engineer, expert in the subject, rails of a different type of steel were substituted, and the new rails remain in good condition after two years' service.

The analytical method of the design of members in construction by applying the principles of mechanics, combined with the experience of test pieces as constants in the formula, is a characteristic of the economy of engineering in its prevention of unnecessary squandering of material, and, above all, in an avoidance of the hazard of destruction from stresses to which the completed work may be subjected.

Another economy may be the attempt to provide for the inevitable result of depreciation from subsequent invention by avoiding the expense of building for too long endurance, but in the expectation that other means will supplant those of the present, and to be prepared for a limited existence of the work.

At the present time there is a great engineering work under construction in this country, in which the whole design is based upon an estimated endurance of fifty years.

It is a credit and not a disparagement to our civilization that it does not undertake to leave works of outlived purpose, like the pyramids, a wonderment to other civilizations.

In the "One Horse Shay," Dr. Oliver Wendell Holmes, as well as the good deacon, builded better than he knew; for it should not be considered merely as a logical triumph, but as an ideal of the accuracy of engineering calculations in correctly estimating the strength of each part, and exactly providing for the depreciation of the whole work.

These instances of the work of the engineer as an economist have been cited merely as examples of the method in which the benefits of enlightened civilization are extended to greater numbers.

All of these works reaching to the benefits of many persons are necessarily founded on an extended scale far greater than would be within the means of any individual to establish or his ability to manage, and therefore the great work of to-day is co-operative in both organization and results, the same as has been the case from all time whenever an enterprise was too great for a private individual.

This united effort for an identical purpose is believed to have been customary ever since men engaged on maritime voyages or caravans, when each contributed to the venture and shared in the results.

This theory of its origin is hypothetical, for co-operation among men is prehistoric, — it is based on the belief of man in his fellow beings; and with the advance of civilization the methods of concentrating the resources of many into a unity of action became wisely formulated, for the Romans had the corporation, as we know it to-day, provided for and regulated in their laws.

The successful efforts in the settlement of America were all done by corporations, and the unsuccessful attempts at colonization which were not permanent were those made directly by governments, without the intermediary of local self-government for the control of the settlers.

The greater strength of a number of persons combined for a unity of effort is not a subject for argument, — as an axiom it is old as Æsop's fable of the bundle of sticks; but its beneficial effects upon the individual, whether as a producer or as a consumer, have not been so fully set forth.

The employment of large numbers is a necessity for extensive production, both of which are essential in connection with the needs of dense population, where there are many people to work and to live.

An extensive establishment must be a corporation, because its financing to bridge the gap between payments for the raw material and labor and the receipts for the product is beyond the resources of the individual, not to mention the large amounts to be buried in plant, which requires constant renewal in part.

The association of many people in an industry by its segregation gives better opportunities to the individual, because the subdivision of work in its assignment according to personal qualifications gives to each one more nearly the class of duties for which he is best fitted, and therefore places him in harmony with his environment, and adds to personal efficiency of production both as to skill and celerity more than can be the case with a variety of duties, as under the completion of any course of work by one person.

The shorter time of instruction for subdivided labor, reduces the period of tutelage at lower wages to far less time than under the apprenticeship system, whose failures cannot be easily corrected in later life.

The history of those occupying places of responsibility in the service of corporations shows the extent to which the principle of selection and promotion has been used to fill vacancies. There have been no premiums on ignorance, but tools to him who can use them.

While it is properly the custom to refer to labor collectively as being made up of individual units, the same method should be used in regard to capital, which is made up of units whose ownership like that of land may be frequently varying.

The capital in a corporation is an aggregation made up of many units, and, as the shares are almost universally on sale at competitive prices, their purchase is available in amounts suited to the resources of the purchaser ; and to this extent they form industrial savings banks, frequently owned in a material part by those who also obtain their livelihood from the same source.

While partnerships are rarely available for those employed by a firm, yet a corporation affords opportunities for part ownerships, and proportional share in profits without the imposition of a personal liability, on the one condition of purchase in the open market.

The relationship between the many units forming the sustaining capital and the many units included in the productive labor joined in an enterprise may be likened to a tree, wherein the trunk between these two parts, each essential to the other, may represent the executive head necessary for both.

These positions of headship require persons who can do many things well, because they can do one thing at a time; and, having a sense to quickly reach logical results from information even outside of their personal knowledge, can therefore give generally correct directions and are endowed with executive capacity.

The methods of correct thinking towards results in the direction of just decisions appear to be developed through legal rather than technical training.

Every executive action reflects an equivalent measure of responsibility, and the conservatism which these conditions inspire is shown in the high standard which pervades the conduct of large establishments.

Attention has been called to some of the events of the centuries whose cumulation prepared mankind to receive higher conditions of welfare, also to the efforts which initiated the means of producing improved conditions of life; and, furthermore, to the later types of engineering skill, whose economies have extended these ameliorations to the benefit of larger numbers.

It is evident that the future will be adorned with these betterments as richly as the past; but, beyond the contingencies of the production of new systems of engineering applications, there will still remain extending fields of work in the savings of wastes of time, labor and material.

This type of modern engineering is largely due to technical education, whose results may not be ascribed so much to those of the departments of instruction directly applicable to practice as they have been to the inculcation of scientific principles and logical methods of procedure, thereby training powers of continuous application; and, above all, the spirit of technical institutions imbuing young minds with the inspiration of a definite purpose.

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